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A PRELIMINARY REPORT ON INTENSITY FORECASTING USING THE TYFOON --ETC(U)
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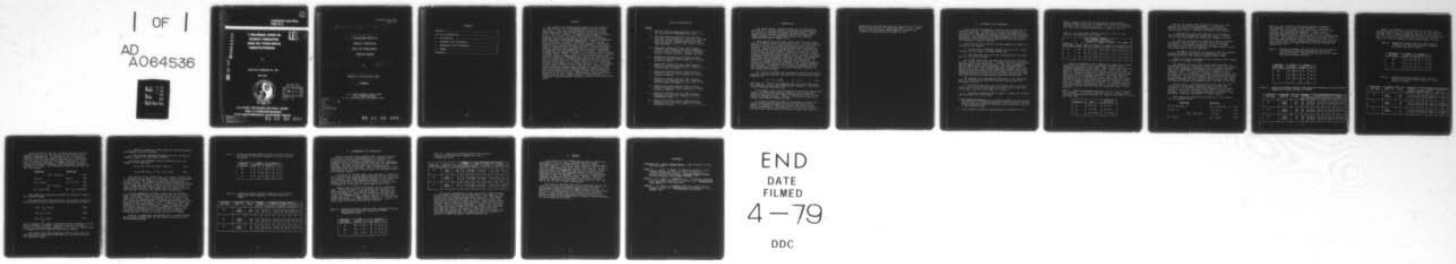

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JTWC 74-2

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A PRELIMINARY REPORT ON INTENSITY FORECASTING USING THE TYFOON ANALOG COMPUTER PROGRAM

by

LCDR LEO H. CRAIGLOW, JR., USN

JUNE 1974

U.S. FLEET WEATHER CENTRAL GUAM
BOX 12 COMNAVMARIANAS
F.P.O. SAN FRANCISCO, CALIFORNIA 96630

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(10) LCDR LEO H. CRAIGLOW JR, USN

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U.S. FLEET WEATHER CENTRAL GUAM
BOX 12 COMNAVMARIANAS
F.P.O. SAN FRANCISCO, CALIFORNIA 96630

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ABSTRACT

The computerized TYFOON analog program has been used by the JTWC as an aid in forecasting tropical cyclone movement since 1970. This study investigated the usefulness of the TYFOON program for forecasting tropical cyclone intensities at 24-, 48-, and 72-hours. It modifies and extends a previous study on this subject by former JTWC personnel. Three parameters which are available on the basic climatological data tape used in the TYFOON program were selected to determine their usefulness in intensity forecasting: These are the minimum sea level pressure, the 12-hour change in minimum sea level pressure, and the maximum sustained surface wind speed. Based on selected values of these criteria, current and analog tropical cyclones were separated into two classes (deepening or weakening) and analog forecasts were computed. During the testing, several changes were made to the classification criteria to obtain better results. Also, it was determined that intensity forecasts computed independently for the various time periods were not consistent. Therefore, the program was modified so that each succeeding intensity forecast used the previous intensity forecast as an input, i.e., initial conditions for the 48-hour forecast would depend on the 24-hour forecast, etc. Verification results based on selected cases from the 1972 tropical cyclone season showed the analog program produced intensity forecasts that were slightly better than the official JTWC forecasts for the 24-hour period but were slightly worse than the official forecasts at 48 and 72 hours. Nevertheless, these preliminary results indicate that further testing of this program is warranted to provide another objective forecast aid to JTWC forecasts.

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1. INTRODUCTION

The TYFOON analog computer program for forecasting the movement of a tropical cyclones in the western North Pacific was originally developed by Hodge and McKay (1970). Modifications to the original program by Jarrell and Somervell (1970) resulted in an operational version first used by FLEWEACEN/JTWC Guam in August 1970.

Upon completion of the 1971 season, major revisions were made to TYFOON by Jarrell and Wagoner (1973). The new version, TYFOON-72, proved to be faster and more accurate, but still provided only forecast positions centered on 50% probability ellipses. Wagoner, prior to leaving the JTWC, instituted the first attempt at using TYFOON to forecast intensities. Using the observed minimum sea-level pressure (P_m) and the 12-hour change in mininum sea-level pressure (ΔP_m), an output of change in minimum sea-level pressure (ΔM_i) per 24 hours was obtained. Only those analog candidates that were included in the 50% probability ellipse position forecasts were considered. If either the minimum sea-level pressure or the 12-hour change in minimum sea-level pressure was missing, that analog candidate was rejected. In addition, if the analog candidate fell outside predetermined limits it was also rejected, otherwise it was accepted and averaged.

If a ΔM_i was provided, the forecaster obtained the forecast minimum sea-level pressure (M_i) for each forecast period using equation (1):

$$M_i = M_{i-1} + \Delta M_i \qquad i = 1,2,3 \qquad (1)$$

where $M_0 = P_m$. Once M_i was computed, the forecaster then used the Takahashi Pressure-Wind Relationship nomogram to obtain the forecast maximum sustained wind.

In the mean, this initial attempt at forecasting intensities using the TYFOON analog program provided forecast pressure changes (ΔM_i) that were too small for deepening storms and too large for weakening storms. Overall, the forecast winds were usually less than the observed winds.

No further attempt was made to investigate intensity forecasting using analogs during 1972 due to the above average number of tropical cyclones (32) and the late extent of the season (19 December). The addition of 1970 and 1971 data to the data base, the extension of the best tracks over land, the

splitting of the data tape into two tapes (one for straight moving storms and one for recurving storms), plus a light tropical cyclone season allowed intensity forecasting research to resume during the summer of 1973.

2. DEPENDENT TEST PROCEDURES

Three necessary parameters, vice two, were chosen for the intensity testing. In addition to the observed minimum sea-level pressure (P_m) and the 12-hour change in minimum sea-level pressure (ΔP_m), the observed maximum sustained surface wind (W_m) was chosen. The addition of the third parameter, it was felt, would allow better definition in the analog selection process for obtaining a forecast intensity.

Data from the 1972 tropical cyclone season were chosen for testing for two reasons:

a. The objective technique computer runs for 1972, along with the initial inputs, had been saved; and

b. The 1972 data was not on the climatological data tape used by the TYFOON Program.

All TYFOON inputs were reviewed and those which contained P_m, ΔP_m, and W_m were extracted. A further editing was performed whereby inputs with glaring errors or those that exceeded the 95% confidence limit were eliminated. The remaining TYFOON inputs, 130 in all, were then divided into straight movers (76) and recurvers (54) based on what would most probably have been chosen operationally during the 1972 season.[1] The official JTWC intensity forecasts as well as the best track[2] intensities were then obtained for the corresponding forecast time periods.

For the test to be considered successful it was specified that the TYFOON analog intensity forecasts should meet the following criteria:

a. Forecast intensities had to be within 20% of the best track winds for 60% of the cases at 24 hours, 55% of the cases at 48 hours, and 50% of the cases at 72 hours.

b. Forecast intensities had to equal or better the official JTWC forecasts 50% of the time.

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1 The author was assigned to the JTWC throughout the 1972 season. The division of the warning positions into straight moving and recurve cases was based on personal recollection and a review of all available data.

2 A post analysis position incorporating all available data.

Table 1 depicts the errors of the official JTWC intensity forecasts used in this test as determined from the corresponding best track intensities for 1972. In none of the cases were over 50% of the official forecasts more than 20% in error.

Table 1. Official JTWC intensity forecast errors for the selected 1972 dependent test cases.

FORECAST TIME (HRS)	NO. OF CASES	JTWC FORECAST ERRORS < × % OF OBSERVED WIND SPEEDS							
		≤10%		≤20%		≤30%		≤40%	
		NO.	%	NO.	%	NO.	%	NO.	%
24	130	51	39.2	87	66.9	105	80.8	120	92.3
48	99	31	31.3	55	55.6	72	72.7	86	86.9
72	70	16	22.9	38	54.3	53	75.7	59	84.3

Jarrell and Wagoner (1973) computed the means and standard deviations for each of the 18 parameters included in the combined climatological data tape. Table 2 gives the values for the three parameters used in this study. These values were computed from the original data tape covering the period 1945-1969. No attempt was made to re-compute the means and standard deviations for both straight moving and recurving tropical cyclones prior to conducting the test. Thus, some error was introduced, that is, the means and standard deviations computed from the original combined data tape are not identical to the means and standard deviations for either the straight moving or recurving tropical cyclone data tapes. In addition, these two tapes also include data from the two additional years of 1970 and 1971.

Table 2. Means and standard deviations for the three necessary test parameters. Values were derived from the original climatological data tape which covered all typhoons and tropical storms from 1945-1969.

Parameter	Mean	Standard Deviation
P_m	979.1 mb	22.9 mb
ΔP_m	-0.4 mb	14.9 mb
W_m	65.6 knots	32.1 knots

Due to the limited time available on Guam's CDC-3100 computer for research and development, a streamlined research version of the TYFOON-72 program was developed. This program, TYFN73, contained three major modifications:

a. Extrapolation position forecasts were eliminated. Since TYFN73 was designed for intensity testing, extrapolation of a position would add nothing but computer run time.

b. The time envelope for accepting an analog candidate was reduced from ±50 days to ±35 days, the time envelope contained in the original operational version of TYFOON. This reduction was done to eliminate non-representative storms from either end of the time spectrum.

c. Automatic cycling and processing of both the straight moving and recurve data tapes was incorporated, thereby speeding operations and saving valuable computer time.

These three major modifications plus numerous minor changes to TYFOON-72, resulted in TYFN73.

Two separate sets of criteria were deemed necessary for determining forecast intensities, depending whether the tropical cyclone was deepening or weakening, e.g., an analog candidate that fits a deepening storm should not be expected to fit a weakening storm. Of the three necessary parameters being utilized, the 12-hour change in minimum sea-level pressure (ΔP_m) was chosen as the critical parameter for determining weakening or deepening. Preliminary testing revealed that if the 12-hour change in minimum sea-level pressure was less than +4mb, then the tropical cyclone was deepening over 75 percent of the time.

For all tests, a necessary condition was that both the test storm and the analog candidate have all three test parameters. In addition, each analog candidate had to pass a series of sufficient conditions to be finally accepted and averaged. Failure of the analog candidate to pass any of the sufficient conditions resulted in it being rejected.

Four sufficient conditions were derived for the initial test as indicated below:

	Deepening	Weakening	
$\Delta P_m \leq 0$ and $\Delta P_a \leq 2$		$\Delta P_m \geq 0$ and $\Delta P_a \geq 0$	(2a)
$P_a - P_m \leq 11$		$P_m - P_a \leq 11$	(2b)
	$\lvert P_m - P_a \rvert \leq 25 \times I$	$I=1,2,3$	(2c)
$W_m - W_a > 15$		$W_a - W_m > 15$	(2d)

where P_a, ΔP_a, and W_a are the analog candidate parameters corresponding to the input storm parameters. Intensity forecasts for each forecast time, stratified using the above criteria, were computed independently. Tables 3 and 4 delineate the test results. Analysis of these two tables show that TYFN73 failed to achieve either of the pre-established criteria. The percent of cases within 20% of the best track winds was below acceptable levels; ranging from -8.0% to -14.4%. The closest TYFN73 came to equalling or bettering the official JTWC forecast was at 24 hours where the official forecast was superior by 7.2%.

Table 3. Comparison between official JTWC intensity forecasts and intensity forecasts computed by the initial version of TYFN73. Figures indicate percent of cases that each forecast was best.

FORECAST TIME (HRS)	JTWC		TYFN73	
	NO.	%	NO.	%
24	67	53.6	58	46.4
48	58	60.4	38	39.6
72	42	60.0	28	40.0

Table 4. Comparison between official JTWC intensity forecast errors and those computed by initial version of TYFN73.

FORECAST TIME (HRS)	FORECAST MADE BY	NO. OF CASES	ERRORS < x % OF OBSERVED WIND SPEEDS							
			< 10%		< 20%		< 30%		< 40%	
			NO.	%	NO.	%	NO.	%	NO.	%
24	JTWC	130	51	39.2	87	66.9	105	80.8	120	92.3
	TYFN73	125	44	35.2	65	52.0	95	76.0	109	87.2
48	JTWC	99	31	31.3	55	55.6	72	72.7	86	86.9
	TYFN73	96	22	22.9	45	46.9	63	65.6	74	77.1
72	JTWC	70	16	22.9	38	54.3	53	75.7	59	84.3
	TYFN73	73	13	17.8	26	35.6	43	58.9	57	78.1

Based on an analysis of the initial test results, the sufficient conditions were modified and the test was repeated. Although TYFN73 intensity forecasts improved in relation to both the official JTWC forecasts and the best track intensities, they still failed to meet the required criteria. After the fourth test run the results were as depicted Tables 5 and 6.

Table 5. Comparison between official JTWC intensity forecasts and intensity forecasts computed by fourth version of TYFN73.

FORECAST TIME (HRS)	JTWC		TYFN73	
	NO.	%	NO.	%
24	56	50.0	56	50.0
48	54	55.1	44	44.9
72	40	57.1	30	42.9

Table 6. Comparison between official JTWC intensity forecast errors and those computed by fourth version of TYFN73.

FORECAST TIME (HRS)	FORECAST MADE BY	NO. OF CASES	ERRORS < x % OF OBSERVED WIND SPEEDS							
			<10%		<20%		<30%		<40%	
			NO.	%	NO.	%	NO.	%	NO.	%
24	JTWC	130	51	39.2	87	66.9	105	80.8	120	92.3
	TYFN73	112	40	35.7	66	58.9	82	73.2	93	83.0
48	JTWC	99	31	31.3	55	55.6	72	72.7	86	86.9
	TYFN73	99	23	23.2	45	45.5	60	60.6	80	80.8
72	JTWC	70	16	22.9	38	54.3	53	75.7	59	84.3
	TYFN73	74	12	16.2	27	36.5	46	62.2	63	85.1

After the fourth test run, it became apparent that the intensity forecasts for 24, 48, and 72 hours could not be computed independently. The variability of the intensity forecasts from one time frame to the next were inconsistent with the input data and the best track intensities. Therefore, to provide continuity, it became necessary for each succeeding intensity forecast to use the previous intensity forecast as an input. The sufficient conditions for the fifth test thus became:

Deepening		Weakening	
	$\lvert \Delta P_m - \Delta P_a \rvert \leq 10$		(3a)
$\Delta P_m \leq 3$		$\Delta P_m > 3$	(3b)
$P_a - P_m \leq 16$		$P_m - P_a \leq 16$	(3c)
	$\lvert P_m - P_a \rvert \leq 22$		(3d)
$W_m - W_a > 0.33 W_m$		$W_a - W_m > 0.33 W_m$	(3e)

The sufficient conditions contained in equation 3 apply to the 24-hour forecast.

The same equations may be used for the 48-hour forecast by substituting P_{m1} for P_m, ΔP_{m1} for ΔP_m, and W_{m1} for W_m, where:

$$\Delta P_{m1} = \sum_{i=1}^{n} \Delta P_{a_i} / N \qquad (4a)$$

$$P_{m1} = P_m + \Delta P_m 1 \qquad (4b)$$

$$W_{m1} = \sum_{i=1}^{n} W_{a_i} / N \qquad (4c)$$

and N represents the number of accepted analog candidates for the 24-hour intensity forecast. Equation 4 may also be used to define the three necessary parameters at 72 hours by substituting the computed 48-hour values for the 24-hour values.

The seventh and final preliminary test was run using the same sufficient conditions as was used on the fifth test with two important changes:

a. Explosive deepeners with already low central pressures were damped out after 24 hours.

b. Weak systems undergoing organization were allowed to intensify rapaidly for the first 24 hours.

The actual relationships used to accomplish these two changes are as indicated:

$$\Delta P_m + 12 \leq 0 \text{ and } P_m \leq 955 \rightarrow \Delta P_m = +8 \qquad (5a)$$

$$W_m \leq 50 \text{ and } \Delta P_m \leq 3 \rightarrow W_m - W_a \leq 0.2W_m \qquad (5b)$$

The results of the seventh test are listed in Tables 7 and 8. Looking first at Table 7, at 24 hours, TYFN73, was superior to the official JTWC forecast by +5.8% and satisfied the second criteria. At 48 hours, TYFN73 was basically even with the official JTWC forecast. Even at 72 hours, TYFN73 was within 5.0%. Comparing these figures with those listed in Table 3 (initial test results), the seventh test was superior by 6.5%, and 9.8% and 7.5% at 24, 48, and 72 hours respectively.

A close examination of Table 8 shows that at 24 hours TYFN73 was within 20% of the best track winds over 60% of the time. At 48 hours, TYFN73 was within 20% of the best track winds 52.3% of the time, just missing the 55% criteria. Only at 72 hours did TYFN73 exhibit a significant deviation from the required criteria, failing by 13.1%. In addition, TYFN73 was superior to the JTWC forecast errors on two occassions: $\leq$30% at 48 hours, and $\leq$10% at 72 hours. Comparing these results with those contained in Table 4 (initial test results), the seventh test was superior in 10 out of the 12 categories; decreasing only at $\leq$10% at 24 hours and $\leq$30% at 72 hours.

Overall, a significant improvement can be claimed between the first and seventh tests of the intensity portion of the TYFOON analog program.

Table 7. Comparison between official JTWC intensity forecasts and intensity forecasts computed by seventh version of TYFN73.

FORECAST TIME (HRS)	JTWC		TYFN73	
	NO.	%	NO.	%
24	56	47.1	63	52.9
48	44	50.6	43	49.4
72	32	52.5	29	47.5

Table 8. Comparison between official JTWC intensity forecast errors and those computed by seventh version of TYFN73.

FORECAST TIME (HRS)	FORECAST MADE BY	NO. OF CASES	ERRORS ≤ × % OBSERVED WIND SPEEDS							
			< 10%		< 20%		< 30%		< 40%	
			NO.	%	NO.	%	NO.	%	NO.	%
24	JTWC	130	51	39.2	87	66.9	105	80.8	120	92.3
	TYFN73	119	41	34.5	75	63.0	91	76.5	104	87.4
48	JTWC	99	31	31.3	55	55.6	72	72.7	86	86.9
	TYFN73	88	26	29.5	46	52.3	65	73.9	74	84.1
72	JTWC	70	16	22.9	38	54.3	53	75.7	59	84.3
	TYFN73	65	16	24.6	24	36.9	37	56.9	51	78.5

3. INDEPENDENT TEST PROCEDURES

Results obtained from dependent data, however good and valid, must still be substantiated by an independent test to verify that the theory or procedure is correct. To accomplish this, 1973 data was saved and used for independent testing. The same criteria used in selecting the 1972 TYFOON data were followed except inputs that exceeded the 95% confidence limit were retained. This, in the author's opinion, would provide an even more critical test for the TYFN73 intensity forecast routine.

A total of 107 TYFOON inputs were available, of which 95 were classified as straight movers and only 12 were classified as recurvers. The large difference between the two categories can be attributed to the anomolous character of the 1973 typhoon season where very few of the tropical cyclones could be thought of as recurvers at some stage in their life.

Tables 9 and 10 reflect the results of the independent test. TYFN73 was equal to the official JTWC forecast at 24 hours and worse than it at 48 and 72 hours. Analyzing the error distribution, both JTWC and TYFN73 did far worse than on the 1972 dependent data. Only at <20% for 24 hours did either exceed 50%. Of significance, however, is the fact that TYFN73 was superior to JTWC on three occassions: $\leq$10% at 24 hours, $\leq$10% at 48 hours, and $\leq$20% at 72 hours.

Table 9. Comparison between official JTWC intensity forecasts and intensity forecasts computed by TYFN73 (Independent Data).

FORECAST TIME (HRS)	JTWC		TYFN73	
	NO.	%	NO.	%
24	51	49.5	52	50.5
48	43	59.7	29	40.3
72	23	56.1	18	43.9

Table 10. Comparison between official JTWC intensity forecast errors and those computed by TYFN73. (Independent Data)

FORECAST TIME (HRS)	FORECAST MADE BY	NO. OF CASES	ERRORS ≤ × % OF OBSERVED WIND SPEEDS							
			<10%		<20%		<30%		<40%	
			NO.	%	NO.	%	NO.	%	NO.	%
24	JTWC	106	31	29.2	63	59.4	82	77.4	93	87.7
	TYFN73	104	34	32.7	55	52.9	67	64.4	82	78.8
48	JTWC	71	13	18.3	30	42.3	50	70.4	55	77.5
	TYFN73	78	16	20.5	32	41.0	41	52.6	48	61.5
72	JTWC	44	8	18.2	11	25.0	16	36.4	25	56.8
	TYFN73	51	9	17.6	13	25.5	17	33.3	23	45.1

The overall degradation of both the official JTWC forecasts and the TYFN73 forecasts can be attributed to the number of 1973 storms that were atypical during their life span. For example, typhoon Patsy went from 80 knots to 140 knots in 24 hours and back down to 80 knots in another 24 hours. Under normal circumstances, Patsy's intensity could have been expected to decrease at about one-half the rate experienced. Finally, the inclusion of those cases that exceeded the 95% confidence limit penalized both JTWC and TYFN73. Exclusion of those cases would have increased the percentages, especially for TYFN73, but would also have been misleading, that is, suggesting that the intensity portion of TYFN73 was better than it actually was.

4. SUMMARY

A new version of the TYFOON analog program, TYFN73, was developed to test an analog intensity forecast scheme. Utilizing 1972 data, a total of seven runs were made on Guam's CDC 3100 computer. After seven runs, TYFN73 met two of six criteria requirements and just missed on two others. Based on these results, an independent test was run using 1973 data. Both the TYFN73 and JTWC forecasts showed a large degree of degradation over the dependent 1972 data due to the anomolous character of many of the 1973 storms. However, TYFN73 still bettered the official JTWC forecast at 24 hours. Neither TYFN73 nor JTWC met the $\leq$20% error criteria of 60%, 55%, and 50% at 24, 48, and 72 hours respectively.

The overall conclusion that can be drawn from this preliminary test is that the intensity portion of TYFN73 shows considerable promise and thus warrants further testing. It should not be expected that the TYFN73 intensity forecasts will ever be of such reliability as to warrant their blind use, however, such forecasts can provide one more useful tool to assist the JTWC in the preparation of tropical cyclone warnings for the western North Pacific.

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